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GROUND WATER IN THE
BALTIMORE AREA, MARYLAND

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GROUND WATER IN THE BALTIMORE AREA, MARYLAND *

ROBERT R. BENNETT

INTRODUCTION

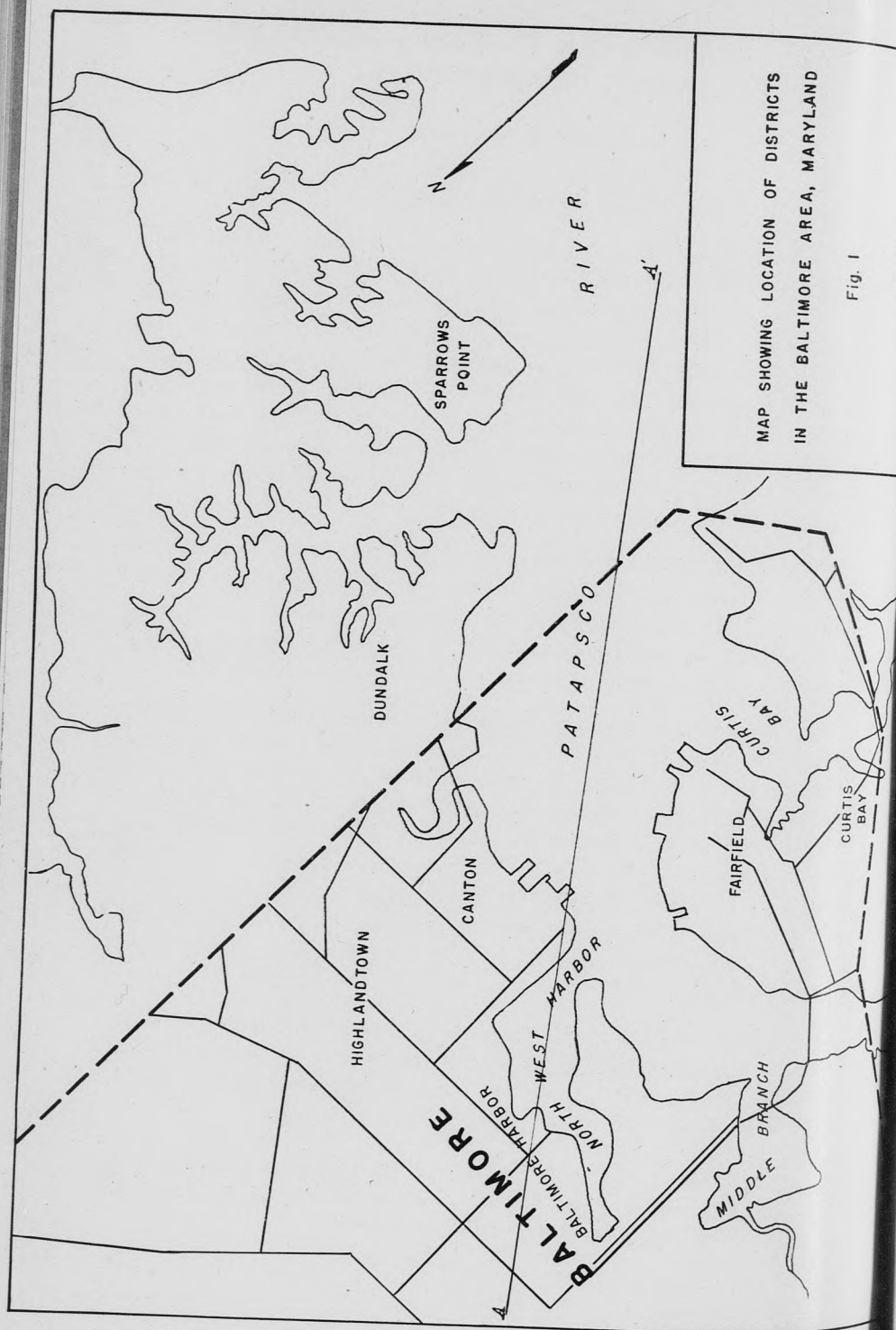
Prior to the construction of a public surface water supply around 1805, the people in Baltimore obtained their water from springs and wells. Most of the wells installed during this early period were dug to shallow depths as the general drilling of artesian wells was not started in this area until about 1853. The use of ground water, however, increased rapidly for by 1860 approximately 100 artesian wells had been drilled in Maryland, nearly all of which were in Baltimore. Most of the wells were drilled close to the Baltimore Harbor district and at that time nearly all furnished ample supplies of good water. The locations of the districts in the Baltimore area are shown in *Figure 1*.

Wells were drilled in the latter part of the 19th century in the Baltimore Harbor district, the Canton district, the Dundalk-Sparrows Point district, and the Curtis Bay district. During this period the ground water supplies were overdeveloped in the Baltimore Harbor district, causing salt water contamination and decrease in yield of some wells.

The use of ground water increased more or less progressively during the 20th century, up to 1942, but the localities of greatest pumpage shifted from the Baltimore Harbor district to the outlying area along the Patapsco estuary. During this period nearly all of the wells in the Baltimore Harbor district and many in the Canton district were abandoned because of contamination from salt or acid waters. The total pumpage of the entire Baltimore area amounted to 50,000,000 gallons daily in 1942. With this quantity of pumpage, the water levels had declined considerably and many of the well fields were being contaminated with salt and acid waters.

It is difficult to place an exact value on the ground water resources in the Baltimore area; however, in monetary terms alone it has been estimated that if the ground water supply were ruined for further use it would represent a net financial loss of about \$1,000,000 a year.

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MAP SHOWING LOCATION OF DISTRICTS
IN THE BALTIMORE AREA, MARYLAND

Fig. 1

Scale

Owing to the serious ground water problems, an investigation of the occurrence of this resource in the Baltimore area was started by the Maryland Department of Geology, Mines and Water Resources in co-operation with the United States Geological Survey, and this study has been in progress since the early part of 1943.

GEOLOGY

The occurrence of ground water is controlled largely by the geologic formations, inasmuch as the character of the rocks and their structure determine to a considerable extent the recharge and movement of ground water, and the yield of wells. Baltimore is on the boundary that separates two physiographic provinces of widely different character, the Piedmont province and the Coastal Plain province. The boundary between these two physiographic provinces is called the Fall Line, which in this area may be considered to extend through the center of Baltimore, in a north-easterly direction. Northwest of this boundary is the Piedmont province, in which the geologic strata consist generally of hard dense crystalline rocks. These rocks contain many fractures and joints that form openings in which ground water may occur. The success of wells drilled in these rocks depends on the number and size of the openings penetrated by the drill. Wells in the crystalline rocks ordinarily yield only a few gallons a minute, but a few yield as much as 200 gallons a minute.

The surface of the crystalline rocks slopes southeastward toward the Atlantic Ocean, and at the Fall Line it passes beneath the Coastal Plain.

The unconsolidated sediments of the Coastal Plain in the Baltimore area are composed chiefly of sand, gravel, and clay of Lower Cretaceous and Pleistocene age. The Cretaceous deposits are divided in ascending order into the Patuxent, Arundel, and Patapsco formations. The Cretaceous strata are overlain by a relatively thin mantle of Pleistocene sediments. The Cretaceous formations dip gently toward the Atlantic Ocean and increase in thickness from a feather edge at the Fall Line to about 700 feet in the Sparrows Point district. A generalized geologic section showing the formations in the Baltimore area is shown in *Figure 2*.

The Patuxent formation which is the basal formation of the Lower Cretaceous series, crops out in an area about five miles in width and extends across Maryland, coinciding approximately with the main line of the Baltimore and Ohio Railroad. In general, the Patuxent formation consists of irregular and lenticular beds of sand, gravel, and clay. Logs of closely spaced wells show that individual beds are not continuous.

however, all of the water bearing beds in this formation function as one because the individual beds are interconnected within relatively short distances. The thickness of the Patuxent ranges from about 75 to 100 feet in the Baltimore Harbor district to as much as 300 feet in the Sparrows Point district. The thickness is somewhat irregular as the formation lies on the uneven surface of the crystalline rocks, which in places contains rather deep valleys that were filled with Patuxent sediments. The Patuxent is the most important water bearing formation in the Baltimore area. Many of the sands and gravels in the Patuxent are very permeable, as indicated by yields of 300 to 900 gallons a minute from many of the wells ending in this formation.

The Arundel formation, which overlies the Patuxent, crops out as a relatively narrow band about two or three miles wide and extends north-eastward, crossing Baltimore in the vicinities of Fort McHenry and Highlandtown. The formation consists essentially of tough clays with a few lenticular beds of sand. The Arundel formation, which is practically impervious, forms an effective confining bed and therefore causes the water in the underlying Patuxent to be under artesian head. The thickness of the Arundel formation ranges from about 25 feet to 200 feet, but in general it is approximately 100 feet thick.

The Arundel is overlain by the Patapsco formation which crops out in a belt that is about five miles wide and extends in a northeastward direction. The lower part of the formation crops out in the vicinity of Brooklyn and Canton and the upper part in the vicinity of Sparrows Point. The Patapsco formation is composed chiefly of irregular and lenticular beds of sand, gravel and clay, and in general the character of the sediments is similar to the sediments of the Patuxent formation. In the Sparrows Point district, the basal sands of the Patapsco are separated from the other water bearing sands of the Patapsco by a thick bed of clay. This bed of clay appears to pinch out to the southeast and therefore the two water bearing sands probably merge southeast of the Sparrows Point district.

The yields of wells indicate that many of the sands and gravels of the Patapsco formation are very permeable. At Sparrows Point, for example, wells in the Patapsco yield as much as 1,100 gallons a minute. The Patapsco ranges from 200 to 300 feet in thickness in areas where the entire formation is present.

Over much of the area these formations of Cretaceous age are capped by sediments of Pleistocene age. The Pleistocene sediments consist of

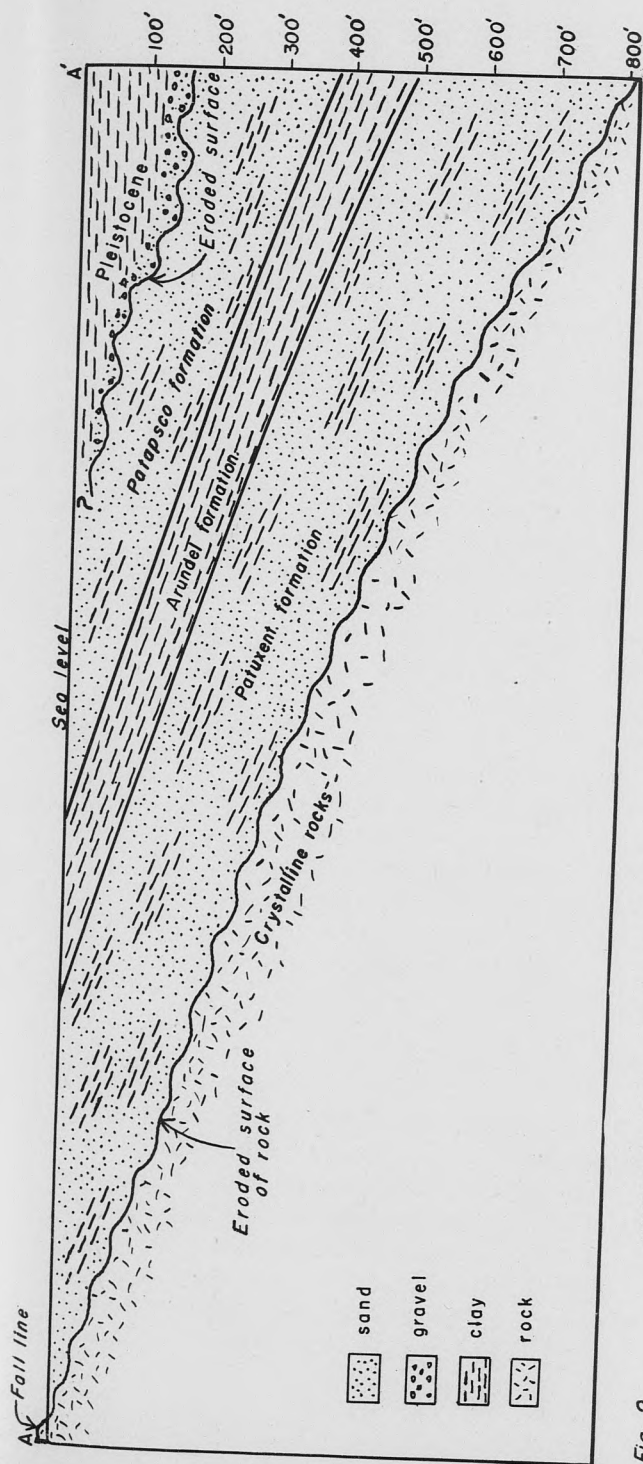


Fig. 2
GENERALIZED GEOLOGIC SECTION ALONG LINE A-A' SHOWN
ON FIGURE 1

lenticular beds of sand, gravel, and clay which were deposited under marine conditions. Their thickness depends largely upon the relief of the surface of the underlying Cretaceous sediments and because of this feature the Pleistocene is absent in some places, although in the Sparrows Point district it is as much as 140 feet thick. The Pleistocene sediments usually can not be distinguished from sediments of Cretaceous age by use of drillers' logs, therefore the areal extent and thickness of the Pleistocene sediments are not well known.

HYDROLOGY

Pumpage:

Nearly all of the ground water that has been withdrawn in the Baltimore area has been consumed by industries. Thus the increase in the consumption of ground water has coincided largely with the industrial growth and the development of efficient well pumps. There are no available records of the quantity of ground water consumed by industries during most of this century, but by piecing together fragments of information, it is roughly estimated that the pumpage in 1900 was 5,000,000 to 10,000,000 gallons daily in the Baltimore Harbor and Canton district, and 1,000,000 to 2,000,000 gallons daily in the outlying parts of Baltimore. The withdrawal probably increased only slightly until about 1915 when it was increased considerably in the Sparrows Point, Dundalk, Canton, and Curtis Bay districts, but probably was decreased in the Baltimore Harbor district. The pumpage is estimated to have been approximately 15,000,000 gallons daily at this time. The ground water consumption increased gradually after the first world war until around 1935, after which it increased rapidly to reach a total of 50,000,000 gallons daily by 1940. In the latter part of 1942, the pumpage was reduced at one large plant by 10,000,000 gallons daily, hence, the total pumpage at the present time (1945) is estimated to be 40,000,000 gallons daily.

The 40,000,000 gallons of water pumped each day comprises 35,000,000 gallons daily from the Patuxent formation and 5,000,000 gallons daily from the Patapsco formation. The pumpage from the Patuxent formation is geographically distributed as follows, in gallons a day: Sparrows Point district, 7,000,000; Dundalk-Canton district, 8,500,000; Highlandtown district, 3,000,000; District near head of Back River, 2,000,000; Baltimore Harbor district, 3,000,000; Fairfield district, 5,500,000; Curtis Bay district, 4,000,000; Miscellaneous, 1,500,000.

The water withdrawn from the Patapsco formation is geographically distributed as follows, in gallons a day: Sparrows Point district, 4,500,000 and Curtis Bay district, 500,000. In general, there is no large withdrawal of water from the Pleistocene sediments. The pumpage from the crystalline rocks on the Piedmont is about 250,000 gallons a day.

Water-level fluctuations:

Extraction of the large quantities of ground water indicated has brought about a substantial lowering of water levels below their original positions. The water levels in most of the wells before 1900 were near the land surface and were sufficiently high in some places to produce a natural flow from the wells. The approximate position of the water level by 1942 in Patuxent wells, recorded in feet below the land surface, was as follows: Sparrows Point district, 150; Dundalk-Canton district, 100; Highlandtown district, 100; Baltimore Harbor district, 50; Curtis Bay district, 100.

The general rate of decline of the water level, by years, is indicated by well-driller records of water levels in the Patuxent wells. These records, showing the year and the water level below the land surface, are as follows:

1909.....	4 feet
1913.....	8 feet
1917.....	15 to 20 feet
1926.....	30 feet
1930.....	50 feet
1932.....	50 feet
1935.....	71 to 77 feet
1936.....	94 feet
1938.....	102 feet
1939.....	115 feet
1940.....	130 to 135 feet
1942.....	150 to 160 feet

The position of the water level in Patapsco wells in the Sparrows Point district had declined by 1942 to 150 feet below the land surface. There is no record of the position of the water level in the Patapsco wells in any of the other districts, but in general it is estimated to have been about 50 feet below the land surface. The pumpage in the Sparrows Point district was decreased, in the latter part of 1942, by about 10,000,000 gallons a day, which in that district caused the water level in the Patuxent wells to rise about 50 feet and the water levels in the lower Patapsco wells to rise about 100 feet. Several observation wells, some equipped with automatic water-level recorders, were established in 1942 and an

accurate record of the water-level fluctuations has been obtained since that time. Up to the present time, this record indicates that in most of the Baltimore area the water levels in the Patuxent wells have remained at about the same elevation since the observations were started.

The pumping levels of some wells in the Curtis Bay district are near the top of the Patuxent formation. A sizeable increase in pumpage in or near these wells will cause the Patuxent formation to become partly unwatered. Such a condition should and can be avoided by distributing the pumpage over a wider area.

The water levels in nearly all of the observation wells fluctuate violently from day to day or even hourly because of tidal effect or changes in the rate of pumpage. Because of these conditions and the short record available it is not possible at this time to predict accurately the future trend of the water levels with the present pumpage.

Quality of water:

The chemical quality of ground water in the Baltimore area is an extremely important factor, since it is put to a variety of uses by the industries. The requirements of the character of water vary considerably; however, most of the industries desire water containing a low content of dissolved minerals and gases for use in boilers and for cooling.

Purely uncontaminated ground water from the Patuxent and the Patapsco formations has only a small amount of dissolved minerals, but it is slightly acid. Fairly representative analyses of uncontaminated ground water from the Patuxent and Patapsco are as follows:

PATUXENT FORMATION

Dissolved Mineral	Parts Per Million
Bicarbonate	5.0
Chloride	2.2
Sulphate	1.6
Iron	0.1
Total solids	19
pH	5.6

PATAPSCO FORMATION

Chloride	8.5
Sulphate	14
Iron	6.6
Total Solids	75
pH	5.6

Few wells in the Baltimore area are now pumping water that is entirely free from contamination, although the water from most of them is only slightly contaminated.

The Patapsco formation in the Baltimore area is contaminated extensively with salt and acid water. A large part of the outcrop of the Patapsco is overlain by salt water such as the Patapsco River estuary. The pumping of large quantities of water from the Patapsco formation lowered the water level in the wells below sea level, hence the salt water moved into the formation. In the Sparrows Point district the basal sands of the Patapsco still contain some uncontaminated water. These sands appear to be partly protected from the infiltration of salt water by an overlying clay bed, however the exact details of this feature are not well understood.

A part of the serious contamination of water in the Patapsco formation is entirely man made. For example, in the Canton district the aquifer that overlies the Arundel and Patuxent formations has been contaminated with sulphuric acid. The origin of this acid probably can be traced to the acid and metal refining plants that were situated in that part of the area many years ago. Acid was spilled accidentally, and the slag from refining plants was dumped on the ground to fill in the hollows or shallow draws in the land surface. The acid water corroded the casings and leaked into the Patuxent wells. It was reported that many years ago one plant proposed to construct a water well for the purpose of recovering the copper sulphate present in the ground water from industrial wastes. It was reported that about thirty-five dollars worth of copper could be recovered from the water pumped each day from a single well. The only difficulty was that no well could be constructed to last more than two years in the corrosive water so the proposal was abandoned.

The water in the Patuxent formation has been contaminated by direct infiltration of salt water only in the Baltimore Harbor district. The Patuxent formation in this district is directly exposed to the salt water in the northwest harbor. In nearly all the other districts the Patuxent is protected from the direct infiltration of salt water by the overlying clay of the Arundel formation. Nevertheless, in some parts of the area the water in the Patuxent formation has been contaminated seriously through leaking wells. Only a few well fields in the Baltimore area are entirely free from contamination through leaking wells. The source of salt and acid waters is from the Patapsco or the Pleistocene sediments that lie at a shallow depth. Wells drilled to the Patuxent formation pass through

the high chloride or acid water in the Patapsco formation or the Pleistocene sediments, thus the iron casing is directly exposed to the highly mineralized water; corrosion takes place and leaks develop. In the past, it has been the general practice to abandon wells when they yielded salt water. Many wells are covered with buildings, pavements, cinders, or have been destroyed and graded over. Many of such wells probably are contributing salt or acid water to the water in the Patuxent formation. An idea of the magnitude of this problem can be obtained from the following figures:

Estimate of number of wells drilled in area since 1850	1,500
Number of wells recorded during present investigation	1,253

Of the 1,253 wells recorded, 959 were located accurately, and 294 were located only approximately. The number of wells that can be seen today is about 360.

Leaks may also occur down the outside of the casings of wells. This may seem improbable as the casings extend through thick sections of clay. However, tests on a well in the Sparrows Point district proved conclusively that salt water was leaking downward outside the casing past the clay of the Arundel formate and entering the well at the top of the screen. In order to investigate this problem more thoroughly an instrument was devised for measuring the diameter throughout the entire length of a newly drilled well before casing is set. Up to the present time, only one well has been surveyed with this instrument and results therefore may not be representative of the entire area. However, in the well surveyed, it was found that the diameter of the well was several inches larger than the size of the drill-bit and that in general the diameter was larger opposite the clay of the Arundel formation.

Several different methods may be used in the investigation of salt water leaks in wells. Those used successfully in the present investigation are:

1. *Salinity pumping tests:* Collection and determination of chloride content of samples taken at short intervals from a pumping well that is turned on after the well has been shut down for a period of two or more hours.
2. *Deep-well current meter studies:* Lowering of a sensitive propeller-type meter into a well to determine any movement of water caused by a leak.
3. *Conductivity surveys:* Lowering of electrode into a well and recording relative conductivity of water.

After salt water leaks in a well have been located it is usually possible to formulate a cementing procedure to stop them. Some wells in the Baltimore area have been cemented successfully and thereby restored to use.

The procedure used for repairing or plugging wells by cementing varies for different wells. A few of the fundamental principles that should be followed for proper cementing of wells are: Cement must be mixed with clean low-chloride water in proportions of $5\frac{1}{2}$ to 10 gallons for each sack of cement, cement must be conducted down the well through a pipe, and cement must be pumped into well in one continuous process. Many wells that have been abandoned and plugged with cement may still be leaking highly mineralized water because they were not properly prepared before plugging. As a general rule, it is the best practice to perforate the casing throughout its entire length before plugging with cement.

Probably the most seriously contaminated districts in the Baltimore area are the Highlandtown, Canton, and Baltimore Harbor districts. The Canton district is contaminated with both salt water and acid water, and for this reason many of the industries in this part of the area have abandoned their wells. This cessation of pumpage allowed the contaminated waters to move northward to the southern part of the Highlandtown district. In this district, the pH of the Patuxent water is as low as 3.2 from sulphuric acid, and the corrosion problems are acute.

Wells in the Baltimore Harbor district yield water with a chloride content of as much as 4,000 parts per million which is about as saline as the water in the northwest harbor. This high chloride water, fortunately, is still being pumped, for the removal of the salt water prevents a large part of it from moving down the dip into the well fields along the Patapsco estuary.

Safe yield of water bearing formations:

Practically all of the ground water pumped in the Baltimore area is derived from precipitation that falls on the outcrops or intake areas of the water bearing formations. This water moves slowly down dip where it is confined by impervious clay beds. The water pumped from the artesian areas is at first derived almost entirely from artesian storage. With a uniform rate of pumpage, the cone of depression gradually expands until it reaches the intake or water table area. The cone of depression is then in essential equilibrium and the artesian head declines very slowly if at all.

Inasmuch as there has been considerable pumpage in the Baltimore area for the last 50 years, it seems reasonable to conclude that most of the water now pumped is obtained from recharge or storage in the outcrop or intake areas. Hence, the quantity of water that may be pumped from the water bearing formations in this area, without lowering the artesian head to excessive limits, is dependent largely on the transmissibility, which is a measure of the formation's capacity to transmit water, and the recharge on the outcrop areas. The determination of these factors is made difficult by the complex stratigraphy of the formations and it may be necessary to drill many test wells to obtain this important information.

The quantity of water that may be safely pumped is limited also by the quality of water. It appears reasonably certain that overpumpage from the Patapsco formation has caused salt water to move into the formation. However, if pumpage were decreased or stopped in this formation the differential head between the Patapsco and Patuxent formations would increase and the salt water contamination through leaking wells would increase. The pumpage from the Patuxent formation in the Baltimore Harbor district probably caused most of the salt water contamination in that section. However, at the present time, it would not be advisable to stop pumpage in this district since this activity prevents most of the salt water from moving down dip and contaminating other well fields.

It is apparent from the foregoing that the determination of safe yield of water bearing formations is complicated by several factors and that the complete answer to this problem must await more detailed information that can be obtained by test drilling and pumping tests.

SUMMARY

The Patuxent and Patapsco formations in the Baltimore area have yielded considerable quantities of ground water for over 50 years and at the present time are yielding about 40,000,000 gallons daily.

Since pumpage first started there has been a substantial decline in water levels, but during 1943 to 1945 the water levels generally have remained at about the same level. Closely spaced pumping wells have caused relatively low pumping levels in some parts of the area and, it appears, in these places the Patuxent may be overdeveloped. A more widespread distribution of pumping wells would result in higher pumping levels and, hence, lower pumping costs.

A large part of the Patapsco and Pleistocene sediments and some parts of the Patuxent formation have been contaminated by the infiltration of salt and acidic waters. The Patuxent and a part of the Patapsco are being further contaminated by leaking wells. Leaking wells can be repaired by cementing.

Much more information is required before all of the details of the occurrence of ground water can be understood. Industries and other ground water users can aid materially in the collection of this information by keeping pumpage records and making periodic measurements of water levels. Many test wells are needed in most parts of the area in order to obtain information on the stratigraphic relationships of the sediments, the quality of water, and the permeability of the water bearing sands and gravel. It is believed that when such detailed information is obtained, remedial measures can be formulated that will perpetuate the valuable supply of ground water in the Baltimore area.